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An Econometric Model of the U.S. Apple Market

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Abstract

An econometric model of the U.S. apple sector was formulated for 1952-81. A system of demand, domestic market allocation, and margin equations were estimated using the two-stage least squares procedure. Retail prices were found to be significantly related to quantity, real per capita expenditures, substitutes complements, and stocks. The signs of the estimated coefficients in the model agreed with theoretical expectations and their magnitudes were statistically significant. A reduced-form solution to the structural model was derived to show the influence of exogenous variables on product prices, margins, and domestic use.

Contents

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Introduction

This study provides an econometric evaluation of the marketing decisions made by apple growers between the fresh and processing markets. More fundamentally, it estimates an appropriate demand structure for those markets. While the marketing decision is made by the grower, the variety and quality of the crop can be a constraint in the allocation process. For example, some varieties are versatile enough to be marketed in either the fresh or processing market, like Golden Delicious, while others are appropriate to only one type of use. In addition, a grower is not able to direct to the fresh market apples which fail to meet Federal and State grading standards because of poor quality.

Final demand for both fresh apples and processed apple products occurs at the retail level. Therefore, grower marketing decisions and the demand decisions by consumers require at least two market levels to be either formally or implicitly recognized and estimated. The econometric model developed in this paper identifies relationships at both the grower and retail market levels for both fresh and processed apples. Market levels are linked by marketing margins.

The Apple Market

At least 35 States within the continental United States commercially produce apples. Nearly 19,000 apple growers produce apples on 485,000 acres with an average orchard size of approximately 24 acres. Apple production has experienced a stable growth rate over the last several years. Record production levels were set in 1978, 1979, and 1980.

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More than 13 major varieties of apples are grown commercially. The single most important variety is Red Delicious, now accounting for approximately 30 percent of the total apple crop; its share is increasing. Golden Delicious and Rome Beauty are the only other apple varieties increasing their share of the market. Only Gravenstein, Winesap, and the Yellow Newton variety are declining in terms of quantity produced; these three varieties accounted for only 5 percent of the 7,767-million pound crop in 1979. There is no apparent tendency for either increased or decreased production of Cortlands, McIntosh, Northern Spy, Rhode Island Greening, Stayman, and York Imperial varieties. Jonathan apple production is increasing, but at a slower rate than the Red Delicious, Golden Delicious, and Rome Beauty varieties. Hence, the relative share of all varieties, except Red Delicious, Golden Delicious, Rome Beauty, and York Imperial is declining significantly.

The State of Washington is the leading producer of both Red and Golden Delicious apples, accounting for more than 50 percent of each crop. Although production is increasing in most States that produce these varieties, the major production increase occurs in Washington. New York is the primary producer of Rome Beauty apples and Michigan is the leading producer of Jonathan apples. Significant varietal differences are apparent across geographic regions. For example, the primary region producing Red and Golden Delicious apples is the West while Jonathans are produced primarily in the Central region. McIntosh and Cortlands are predominantly produced in the Northeast. A number of factors account for this regional specialization among varieties including climate, end-product use, and varietal characteristics.

The apple-producing sector is undergoing a technological change because growers are replacing standard trees in their orchards with spur, semi-dwarf, and dwarf rootstocks which enable producers to increase the tree density of their orchards (see Ricks and Pierson, 1980). This replacement, beginning in the fifties, has increased the productive capacity of the industry while acreage has declined. Increases in production will probably slow as this replacement process nears completion.

Apples are marketed in either the fresh or processing markets. However, some varieties are more specific to one end-use while others can easily be used fresh or in processing. In the early fifties as much as 70 percent of the total U.S. crop was marketed in the fresh market. Current shares are about 60 percent for fresh and 40 percent for processing.

Processed apples are marketed in four basic forms: canned, dried, frozen, and a category including juice and cider. An increasing amount is being processed as canned, frozen, and other product forms, but the share of dried product is declining:

Form	1950-52	1976-78
	Percentage share of total apple market	
Canned	12.7	15.6
Dried	4.2	3.3
Frozen	1.4	2.8
Other products	11.0	20.6

An increasing proportion of the U.S. apple crop is marketed to the processed market. Certain apple varieties have attributes which allow them the flexibility to be marketed in either the processing or fresh markets. For example, the apple varieties that are increasing in importance, such as Golden Delicious, Rome Beauty, and, to some degree, Jonathans, can be marketed in either the fresh or processing market. The processing market offers more flexibility in marketing strategies simply because of the large number of product forms and the extended shelf life of these product forms relative to the fresh market. Red Delicious apples are predominantly a fresh market variety and capture much of the fresh market.

Foreign trade plays a relatively minor role in the U.S. apple sector. The United States has exported from 1950-77, on average, approximately 3.4 million bushels of fresh apples and 563,000 bushels (fresh equivalent) of processed apples. This amounts to less than 4 percent of the U.S. apple crop. Nonetheless, exports of fresh market apples are increasing at approximately 86,000 bushels per year, while processed apple exports are declining at a rate of 29,000 bushels per year. The net effect is that exports are increasing at 57,000 bushels per year.

The United States also imports about 44,000 bushels of apples and apple products per year. However, apple imports have never exceeded 2 percent of total U.S. production. Net trade is exports of approximately 13,000 bushels of apples and apple products per year.

Consumption patterns tend to follow the same or similar patterns of commodity utilization. Total apples consumed have increased, but the rate of population growth has exceeded the rate of consumption. Therefore, per capita figures have fallen since 1950.

The aggregate per capita production of all processed apples has increased. In 1950-52, per capita processed apple production was 43.8 pounds; the figure is now around 56 pounds per capita. The increase in per capita processed apple production is largely a result of significant increases in juice and frozen product consumption.

An Overview of the Theoretical Model

An aggregate model detailing the allocation and demand components of the U.S. apple sector is hypothesized and estimated in this paper. In the short run, quantity supplied is relatively fixed and price is determined by demand. As a result, retail demand functions for both fresh and processing market apples are specified as inverse demand functions based on utility maximization.

There is an interrelationship between the amount the consumer pays per unit (retail price) and the amount the grower receives per unit (farm price). The difference between these two prices is called the marketing margin. The size of the marketing margin reflects the costs of marketing services (packaging, processing, transportation, advertising, and profits) required to bring the product from the grower to the eater. Margins are specified to reflect the costs of marketing services for both the fresh and processing apple markets.

The model structure hypothesized has six behavioral relationships and four identities. The behavioral equations are: 1) total utilization, 2) amount marketed to the processing market, 3) retail demand for fresh apples, 4) retail demand for processing apples, 5) the fresh market marketing margin and 6) the processing market marketing margin. Four identities are specified to determine the fresh and processing marketing margins, a market-clearing identity, and total utilization identity. All of the behavioral and deterministic relationships are presented below.

(1.1) <u>Total Apple Supply to Fresh and Processed</u>

$$UTIL = f_1(PROD, PPF, *PPR)$$

(1.2) <u>Supply of Apples to Processing Market</u>

$$UTPR = f_2(PPR, UTIL)$$

(1.3) <u>Retail Demand, Processing Apples</u>

$$WPABSB = f_3(UTPR, OTHPRC, PORIR, STCAP, EXP)$$

(1.4) <u>Retail Demand, Fresh Apples</u>

$$RPFAP = f_4(UTFR, USORAN, EXP)$$

(1.5) <u>Margin, Fresh Apples</u>

$$MARFR = f_5(RPFAP, TRANS)$$

(1.6) <u>Margin, Processing Apples</u>

$$MARPR = f_6(WPABSB)$$

(1.7) <u>Production Identity</u>

$$PROD = UTFR + UTPR + OTHPRD$$

(1.8) <u>Utilization Identity</u>

$$UTIL = UTFR + UTPR$$

(1.9) <u>Fresh Farm Price Identity</u>

$$PPF = - MARFR + RPFAP$$

(1.10) <u>Processed Farm Price Identity</u>

$$PPR = - MARPR + WPABSB$$

where:

EXP = real per capita expenditures income, 1,000 dollars, calendar year basis

MARFR = fresh apple marketing margin, cents per pound

MARPR = processing apple marketing margin, cents per pound

OTHPRC = total consumption of processed fruit excluding apple products, million pounds, calendar year basis

OTHPRD = quantity of apples not utilized in either the fresh or processing market, million pounds, marketing year September-August

PFR = real average price received by growers for fresh market apples, cents per pound

PORIR = real U.S. pork price, index

PPR = real average price received by growers for processing grade apples, cents per pound

PROD = total quantities of apples produced in the United States, million pounds, marketing year September-August

RPFAP = real retail price of fresh market apples, cents per pound, calendar year basis

STCAP = beginning stocks of canned apples, 1,000 pounds

TRANS = index of all urban consumers transportation CPI (1967=100), calendar year basis

USORAN = total quantities of oranges produced in the United States, 1,000 tons

UTFR = quantity of apples utilized in the fresh market, million pounds, marketing year September-August

UTIL = quantity of apples utilized in both the fresh and processing markets, million pounds, marketing year September-August

UTPR = quantity of apples utilized in the processing market, million pounds, marketing year September-August

WPAPSB = real wholesale price of applesauce, cents per pound, calendar year basis.

Quantities supplied, quantities demanded, and prices are determined simultaneously in the system of equations described above. Therefore, the two-stage least squares (2SLS) procedure was used to estimate the theoretical relationships given the simultaneous nature of the apple model. Structural parameter estimates are based upon annual time series data from the 1952-81 sample period.

Data and sources are shown in Appendix 1. All price and income variables are deflated by the consumer price index at the retail level and by the producer price index at the wholesale level. The equations and empirical results are discussed in more detail below.

The Estimated Model

Total Apple Utilization

The total amount of apples supplied (UTIL) is assumed to be a function of the price received by growers for fresh (PPF) and processing (PPR) market apples and the level of production (PROD).

The total amount marketed in the fresh market and those processed varies directly with the level of total apple production. If prices of fresh market apples and processing market apples are high enough at the farm level, only then will marginal quality apples be utilized. Otherwise, the marginal apples will not be utilized. The empirical results are presented in equation (2.1).

$$\underset{(-1.643)}{UTIL = -381.330} + \underset{(40.562)}{1.00426*PROD} + \underset{(2.52)}{14.4073*PPF} + \underset{(0.785)}{80.0048*PPR} \;\; \text{1/} \qquad (2.1)$$

The 2SLS results suggest that there is a negligible price response with respect to supply. This is a likely outcome since higher grower prices may increase the level of marketing of marginal apples that would otherwise be discarded or abandoned, but little else. The magnitude of the coefficient for processor grower prices is five times greater than the coefficient for fresh market, thereby suggesting that increases in the processing price are reallocating some apples that otherwise might be abandoned into the processing market. Grade standards inhibit the use of inferior quality apples in the fresh market and would reduce any possibility of reallocating marginal apples.

Supply of Apples to the Processing Market

Apples may be supplied to either the fresh or processing markets. However, the U.S. grade standards restrict free marketing between both sectors where marketing orders exist and thus place a constraint on the flow of apples to the fresh market in those areas. Theoretically, one would expect that when the price received in one market for a "homogeneous" product increases, the amount supplied to that market will increase, *ceteris paribus*. This strategy does not occur for processing apple marketing since grading standards differentiate apples into heterogeneous commodities. Indeed, the quantity marketed to the processing sector is not significantly influenced by fresh market prices. Marketing of apples to the processing sector (UTPR) is assumed to be a function of the processing apple price (*PPR) and total utilization (UTIL). A significant relationship exists between the dependent and explanatory variables as reported in equation (2.2).

1/ Numbers in parentheses are asymptotic t-statistics.

$$UTPR = -2080.29 + 18.6592*PPR + 0.670013*UTIL \quad (2.2)$$
$$(-5.558) \quad (2.190) \quad (16.306)$$

An informal interpretation of the estimated structural parameters would suggest that 67 percent of all apples supplied will be allocated to the processing market and that for every 1 cent per pound increase in the real farm-level processing apple price, utilization in the processing sector increases by nearly 19 million pounds. However, the estimated structural parameters should not be strictly interpreted out of context of the entire simultaneous system.

Retail Demand for Fresh Apples

The basic theory underlying the specification of the retail demand for fresh market apples is the familiar one of utility maximization (see Henderson and Quandt, 1980, p. 13). An inverse demand function is hypothesized where the deflated retail price (RPFAP) is a function of the quantity demanded (UTFR), the quantity of alternatives demanded (USORAN), and per capita real expenditures (EXP). Equation (2.3) shows the estimated equation.

$$RPFAP = 19.6204 - 0.00224205*UTFR + 0.000257315*USORAN + 3.16528*EXP \quad (2.3)$$
$$(8.675) \quad (-3.628) \quad (1.375) \quad (3.005)$$

A positive relationship exists between the retail price of fresh apples and the quantity of oranges produced which serves as a proxy for orange or citrus consumption. While some earlier studies (see, for example, Tomek, 1963, George and King, 1971, Brandow, 1965) suggest that oranges and apples are substitutes, our results follow Mathews, Womack and Huang (1974) and indicate that a complementary relationship exists between the two. Since apples decomposed into qualitative attributes represent bulk while oranges represent vitamin C, a complementary relationship is not inconceivable or unlikely. In addition, Henderson and Quandt suggest that goods can be substitutes as defined by the Slutsky term and yet still be gross complements because the income effect may dominate the substitution effect.

Retail Demand for Processing Apples

The deflated wholesale processing apple price (WPAPSB) is a function of the quantity processed (UTPR), other fruit processed (OTHPRC), U.S. real retail pork price (PORIR), per capita real expenditures (EXP), and beginning stocks of canned apples (STCAP). The wholesale price of applesauce is used as a proxy for the retail processing price out of necessity since no retail composite price for processing apples exists. Inventory accumulations in the control of buyers such as food manufacturers and distributors may influence prices. Following Brandt and French (1982), the stock variable is added to years and, therefore, one might view this equation more accurately as a "retail-wholesale" aggregate specification. The level of processing utilization does not measure the true demand at the retail level and therefore stocks must be introduced. Inventories do appear to significantly influence the processor's demand for apples. Equation (2.4) shows this result.

$$WPABSB = \underset{(9.545)}{22.3464} - \underset{(-4.545)}{.00493355*UTPR} - \underset{(-1.642)}{0.000833894*OTHPRC} + \underset{(3.585)}{4.6368*PORIR} -$$

$$-\underset{(-2.93)}{0.00000129255*STCAP} + \underset{(1.606)}{4.10628*EXP} \qquad (2.4)$$

Signs of all the coefficients are as expected. The U.S. pork retail price suggests a complementary relationship with processing apples (applesauce is often served with pork) and other processed fruit is a substitute for processing apples. Beginning stock levels show a negative relationship with wholesale processed apple price and real per capita expenditures is positively related to retail price.

Marketing Margin Relationships for Fresh and Processed Apples

The marketing margin is defined as the difference between the per unit price paid by the consumer and the price received by the producer. The size of the margin reflects the costs of goods and services provided in the marketing process (see Tomek and Robinson, 1980, pp. 120-122). The basic premise underlying each of the two behavioral margin relationships estimated is that both a constant and percentage markup in retail prices exist. The margin may then be assumed to be a linear function of the retail price and an intercept. This approach has been characterized as an accurate reflection of wholesaler and retailer behavior by another recent study (see Steadman, 1976).

The marketing margin for fresh apples (MARFR) is a function of the retail fresh apple price (RPFAP). The transportation rate index is included to recognize changes in the transportation industry during the seventies, particularly increased fuel costs. The marketing margin for processing apples (MARPR) is a function of the wholesale price of processing apples (WPAPSB). Results are shown in equations (2.5) and (2.6), respectively.

$$MARFR = \underset{(3.570)}{4.56858} + \underset{(6.066)}{0.427*RPFAP} + \underset{(4.452)}{0.00240189*TRANS} \qquad (2.5)$$

$$MARPR = \underset{(0.646)}{0.570} + \underset{(15.910)}{0.828 * WPAPSB} \qquad (2.6)$$

All explanatory variables in each respective equation have the anticipated positive influence on the dependent variable.

Demand and Supply Flexibilities and Elasticities for Processing and Fresh Apples at the Retail and Farm Levels--Their Calculation and a Comparison

Direct calculations of price flexibilities from the estimated structural equations presented earlier are not strictly valid. As Haidacher and Penn (1974) note, both price and quantity are endogenous to the system, and measurement of price responsiveness to quantity changes is, therefore, restricted. With that caveat for the reader, estimates of price flexibilities and price demand elasticities are now derived from the structural equations and summarized below. Even though the estimates are not strictly correct, they do yield a useful yardstick for comparison with other empirical studies.

Price flexibilities and elasticities are derived for both fresh and processing market apples at both the retail and farm-market levels. The elasticity estimate is calculated as the reciprocal of the flexibility estimate and represents a lower bound of the measure (Houck, 1965). A detailed discussion of the derivation of the flexibilities and elasticities is worthwhile given the insights it lends to the interdependent nature of the market.

The derivation of the price flexibilities and demand elasticities for fresh and processing grade apples is shown at both the retail and farm levels. All elasticity and flexibility estimates are evaluated at their means. Structural parameter estimates are used as a proxy for changes in price with respect to changes in quantities. They represent a proxy because, in a simultaneous system where both prices and quantities are endogenous to the model, the partial derivative of price (quantity) with respect to quantity (price) is not a valid measure (Haidacher and Penn, 1974). For that reason, the partial derivative is used only as an approximation to the actual changes in the system. The price flexibility may be defined as:

$$F = \frac{\partial P}{\partial Q} \frac{Q}{P} \tag{3.1}$$

Houck (1965) points out that the simple inverse of the price flexibility is a lower bound for the elasticity of demand

$$\varepsilon = 1/F \tag{3.2}$$

The grower and retail marketing levels are identified in the estimated apple model. Therefore, demand elasticities and price flexibilities can be measured at each market level. The two levels, as specified in the empirical model, are related through the marketing margin relationship. By definition, the demand elasticity (and price flexibility) is the same at each market level. However, the retail price and farm-level price must be used to measure the price or quantity response.

The farm-level price flexibility is derived in the following manner:

$$F^f = \frac{\partial P^f}{\partial Q^f} \frac{Q^f}{P^f} \tag{3.3}$$

where superscript f denotes farm or grower level, P is price, and Q is quantity. Multiplying (3.3) by:

$\frac{\partial P^R}{\partial Q^R} \frac{\partial Q^R}{\partial P^R} \frac{P^R}{P^R}$, which equals one, where superscript R denotes that retail level. Then,

$$F^f = \frac{\partial P^f}{\partial Q^f} \frac{\partial Q^R}{\partial P^R} \frac{\partial P^R}{\partial Q^R} \frac{P^R}{P^R} \frac{Q^f}{P^f} \qquad (3.4)$$

Noting that Q^R and Q^f are equal, (3.4) simplifies to

$$F^f = F^R \left(\frac{\partial P^f}{\partial P^R} \frac{\partial P^R}{\partial P^f} \right) \qquad (3.5)$$

The expression in the parentheses of (3.5) can be expressed in an alternative form. First, the margin (M) is the difference between the retail and farm prices.

$$M = P^R - P^f \qquad (3.6)$$

The margin is estimated as a function of the retail price

$$M = f(P^R) \qquad (3.7)$$

Substituting for M in (3.7), rearranging terms and solving for the retail price, P^R, we obtain

$$P^R = g(P^f) \qquad (3.8)$$

Equation (3.8) is used to derive the elasticity of price transmission. This is a measure of the price responsiveness at the retail level resulting from changes in the grower price level.

$$e = \frac{\partial P^R}{\partial P^f} \frac{P^f}{P^R} \qquad (3.9)$$

where e is the elasticity of price transmission.

Substituting (3.9) into (3.5) results in

$$F^f = F^R\left(\frac{1}{e}\right) \qquad (3.10)$$

The lower bound estimate of the elasticity of demand at the farm level is given by

$$\varepsilon^f = \frac{1}{F^f} \qquad (3.11)$$

Equations (3.1), (3.2), (3.9), (3.10), and (3.11) are used to estimate the price flexibilities and demand elasticities at the retail and farm levels for fresh and processing apples. F denotes flexibility, ε is the elasticity of demand, subscripts F and P indicate fresh and processing apples, respectively, and superscripts R and f differentiate between the retail and farm level, respectively.

Price Flexibility for Fresh Apples, Retail Level

$$F_F^R = \frac{\partial RPFAP}{\partial UTFR} \frac{UTFR}{RPFAP}$$

$$= -0.0024 \left(\frac{3619.4}{19.886}\right)$$

$$= -0.437$$

Elasticity of Demand for Fresh Apples, Retail Level

The value of F_F^R infers a lower bound estimate of the elasticity of demand for fresh apples at the retail level of

$$\varepsilon_F^R \qquad \frac{1}{F^R}$$

$$= 1/-0.437$$

$$= -2.288$$

Price Flexibility for Fresh Apples, Farm Level

The elasticity of price transmission for fresh apples is

$$e_F = \frac{\partial RPFAP}{\partial PFR} \frac{PFR}{RPFAP}$$

$$= \left(\frac{1}{0.573}\right)\left(\frac{5.65}{19.886}\right)$$

$$= 0.496$$

Then the farm level price flexibility is

$$F_F{}^f = F_F{}^f\ (1/e_F)$$

$$= -0.437\ (1/0.496)$$

$$= -0.881$$

Elasticity of Demand for Fresh Apples, Farm Level

The value of $F_F{}^f$ indicates a lower bound estimate for the elasticity of demand at the farm level for fresh apples of

$$\varepsilon_F^f \quad 1/F_F{}^f$$

$$= 1/-0.881$$

$$= -1.135$$

Price Flexibility for Processing Apples, Retail Level

$$F_P^R = \frac{\partial RPAPSB}{\partial UTPR}\ \frac{UTPR}{RPAPSB}$$

$$= -0.0049\left(\frac{2366.9}{16.859}\right)$$

$$= -0.688$$

Elasticity of Demand for Processing Apples, Retail Level

The value of F^R infers a lower bound estimate of the elasticity of demand for processing apples at the retail level of

$$\varepsilon_P^R = 1/F_P{}^R$$

$$= -1.453$$

Price Flexibility for Processing Apples, Farm Level

The elasticity of price transmission for processing apples is

$$e_p = \frac{\partial RPAPSB}{\partial PPR} \frac{PPR}{RPAPSB}$$

$$= \left(\frac{1}{0.172}\right)\left(\frac{2.338}{16.859}\right)$$

$$= -0.806$$

Then, the farm-level price flexibility is

$$F_p^f = F_p^R \frac{1}{e_p}$$

$$= -0.688 \quad 0.806$$

$$= -0.854$$

Elasticity of Demand for Processing Apples, Farm Level

The value of F_p^f implies a lower bound estimate of the elasticity of demand for processing apples at the farm level of

$$= 1/F_p$$

$$= 1/-0.854$$

$$= -1.171$$

The price flexibility estimates for fresh apples indicate an elastic demand at the retail level and less elastic demand at the grower level. The flexibility measure at retail is -0.437 and at the grower level is -0.881. The coefficient estimate on quantity is significant in the retail fresh apple demand equation, assuming the ratio of the estimate to the standard error is distributed in an approximate student t distribution. The elasticity estimates reported below in table 1 are the simple inverse of the respective flexibility estimates.

Table 1--Estimated price flexibilities and elasticities for fresh and processing apples

Item	Fresh apples	Processing apples
Price flexibility, retail level	-0.437	-0.688
Demand elasticity, retail level 1/	-2.288	-1.453
Price flexibility, farm level	-.881	-.854
Demand elasticity, farm level 1/	-1.135	-1.171

1/ Represents a lower bound; calculated as a reciprocal of the price flexibility.

Many studies have attempted to measure the elasticity and/or price flexibility of fresh apples at alternative market levels and a wide range of estimates have emerged. However, no consensus has formed as to the "correct" estimate. For example, Tomek (1968) concludes that the elasticity at the farm level ranges between -0.8 and -0.7 and between -1.2 and -0.105 at the retail level. Price and Mittelhammer (1979) and Brandow (1956) estimate the elasticity of demand to be lower than the range asserted by Tomek, -0.596 and -0.35, respectively, at the grower level. Pasour (1965) estimated the interseasonal demand at the farm level over three seasons and found the elasticity estimates to range from -0.35, over July to November, to -1.85 over an April-June period.

Waugh (1964) tends to confirm Tomek's inelastic-elastic demand relations at the grower and retail levels. However, Brandow (1956) and George and King (1971) find an inelastic demand at the retail market level, namely -0.6 and -0.72, respectively. Intraseasonal studies by Edman (1972), Steadman (1976), and Hallberg, et al. (1978), indicate an elastic demand for fresh market apples at both the farm and retail levels. Yet the results found in this study suggest a more elastic demand at retail and farm levels relative to earlier works based on annual data. However, there is a strong consistency in our results with intraseasonal studies.

There appears to be stronger support for an elastic demand for processing apples at both the grower and retail levels. Drew (1961), however, estimated the direct elasticities for canning apples as -0.73. Tomek (1968) found the direct elasticity for canning apples to be -1.21 at the farm level and the elasticity for other processing apples to be -0.76. Steadman (1976) concludes that the grower level flexibility estimate for processing apples is -0.435 (-0.57 at the retail level). French (1956) found that the demand for all apples is elastic, with -1.19 as the direct elasticity estimate. In sum, the estimated flexibility and elasticity results for processing apples are consistent with earlier works. A 1-percent change in the quantity demanded produces a 0.69-percent change in price at retail and a 0.85-percent change in price at the farm level.

Now we shall derive the income flexibility, which is defined as the percentage change in the price with respect to a percentage change in income, and the income elasticity, defined as the percentage change in quantity demanded with respect to a percentage change in income. An income flexibility and elasticity is estimated for both fresh and processing apples. The income flexibility is mathematically defined as

$$F_y = \frac{\partial P}{\partial Y} \frac{Y}{P} \tag{4.1}$$

and the income elasticity is defined as

$$\varepsilon_y = \frac{\partial Q}{\partial Y} \frac{Y}{Q} \tag{4.2}$$

For equations (4.1) and (4.2), F is the flexibility, ε is the elasticity, and P, Q, and Y represent price, quantity, and income, respectively.

The income flexibility and income elasticity are related and this relationship can be shown mathematically. Multiply (4.2) by

$\frac{\partial Y}{\partial P} \frac{\partial P}{\partial Y} \frac{P}{P}$, which equals one, then

$$\varepsilon_y = \frac{\partial Q}{\partial Y} \frac{\partial Y}{\partial P} \frac{\partial P}{\partial Y} \frac{P}{P} \frac{Y}{Q} \tag{4.3}$$

Simplifying,

$$\varepsilon_y = |\varepsilon_o| * F_y \tag{4.4}$$

The income elasticity equals the product of the elasticity of demand (absolute value) and the income flexibility.

The income flexibility and elasticity may be derived at both the retail and grower levels. As described earlier, the two market levels are linked through the marketing margin. Letting superscript f and R denote the farm and retail level, respectively, then

$$F_Y^f = \frac{\partial P^f}{\partial Y} \frac{Y}{P^f} \tag{4.5}$$

Multiplying (4.5) by

$$\frac{\partial Y}{\partial P^R} \quad \frac{\partial P^R}{\partial Y} \quad \frac{P^R}{P^R}$$, a form of one, then

$$F_Y^{\ f} = \frac{\partial P^f}{\partial Y} \quad \frac{\partial Y}{\partial P^R} \quad \frac{P^R}{P^f} \quad \frac{P^R}{Y} \quad \frac{Y}{P^R} \tag{4.6}$$

Simplifying, (4.6) becomes

$$F_Y^{\ f} = F_Y^{\ R}\left(\frac{1}{e}\right) \tag{4.7}$$

where e is the elasticity of price transmission discussed earlier.

Equations (4.1), (4.4), and (4.7) are used to estimate the income flexibility and elasticity for fresh and processing apples at the retail and grower levels. Subscripts F and P refer to fresh and processing apples, respectively. The flexibility and elasticity estimates are evaluated at their mean values.

Income Flexibility for Fresh Apples, Retail Level

$$F_{YR}^{\ R} = \frac{\partial RPFAP}{\partial EXP} * \frac{EXP}{RPFAP}$$

$$= 3.165 \left(\frac{2.08}{19.886}\right)$$

$$= 0.331$$

Income Elasticity for Fresh Apples, Retail Level

$$\varepsilon_{YF}^{\ R} = \left|\varepsilon_F^R\right| * F_{YF}^{\ R}$$

$$= 2.288 * 0.331$$

$$= 0.757$$

Income Flexibility for Fresh Apples, Farm Level

$$F_{YF}^{f} = F_{YR}^{R} \quad \frac{1}{e_F}$$

$$= 0.331 * 1/0.496$$

$$= 0.667$$

Income Elasticity for Fresh Apples, Farm Level

$$\varepsilon_{YF}^{F} = |\varepsilon_F^{f}| * F_{YF}^{F}$$

$$= -1.135 * 0.667$$

$$= 0.757$$

Income Flexibility for Processing Apples, Retail Level

$$F_{YP}^{R} = \frac{\partial RPAPSB}{\partial EXP} \quad \frac{EXP}{RPAPSB}$$

$$= 4.106 * \frac{2.08}{16.859}$$

$$= 0.507$$

Income Elasticity for Processing Apples, Retail Level

$$\varepsilon_{YP}^{R} = \varepsilon_P^{R} * F_{YP}^{R}$$

$$= 1.453 * 0.507$$

$$= 0.737$$

Income Flexibility for Processing Apples, Farm Level

$$F_{YP}^{f} = F_{YP}^{R} * \frac{1}{e_p}$$

$$= 0.507 * \frac{1}{0.806}$$

$$= 0.629$$

Income Elasticity for Processing Apples, Farm Level

$$\varepsilon_{YP}{}^{f} = \left|\varepsilon_{P}{}^{f}\right| * F_{YP}{}^{f}$$

$$= 1.171 * 0.629$$

$$= 0.737$$

The estimates of the income elasticities at the retail and farm level are equal, except for rounding error, for both fresh and processing apples. This can be shown to be true for all structural models formulated in a manner consistent with the specification presented here. The proof is as follows:

Equation (3.2) states

$$\varepsilon = 1/F \tag{4.8}$$

The elasticity of demand estimate at the specified market level is the reciprocal of the price flexibility measure at that same market level.

Equation (4)

$$\varepsilon_{y} = |\varepsilon|\ F_{Y} \tag{4.9}$$

The income elasticity at the market level is the product of the absolute value of elasticity of demand and the income flexibility at the same market level.

The relationship between income flexibilities at the retail and grower levels is specified by equation (4.7)

$$F_{Y}{}^{f} = F_{Y}{}^{R} * \left(\frac{1}{e}\right) \tag{4.10}$$

The income flexibility at the farm-market level equals the product of the income flexibility at the retail level and the inverse of the elasticity of price transmission.

Equation (4.10) indicates a similar relationship for price flexibilities between the grower and retail levels.

$$F_{Y}^{f} = F_{Y}^{R} * \left(\frac{1}{e}\right) \tag{4.11}$$

The income elasticities at the retail and farm-market levels are presented in equations (4.12) and (4.13), respectively.

$$\varepsilon_Y{}^R = |\varepsilon^R| F_Y{}^R \qquad (4.12)$$

$$\varepsilon_Y{}^R = |\varepsilon^f| F_Y{}^f \qquad (4.13)$$

Substituting for ε^f, from (4.8), and $F_Y{}^f$, from (4.10), into (4.13) results in

$$\varepsilon_Y{}^f = \frac{1}{F^f} \quad \frac{F_Y{}^R}{e} \qquad (4.14)$$

Note that the denominator equals the retail price flexibility from (4.11). Simplifying (4.14) results in

$$\varepsilon_Y{}^F = \left|\frac{1}{F^R}\right| F_Y{}^R \qquad (4.15)$$

$$\varepsilon_Y{}^F = |\varepsilon^R| F_Y{}^R \qquad (4.16)$$

Therefore,

$$Y^F = Y^R \qquad \text{Q.E.D.} \qquad (4.17)$$

The income flexibilities and elasticities for fresh and processed apples are also reported in table 2.

Table 2--Estimated income flexibilities and elasticities for fresh and processing apples

Item	Fresh apples	Processing apples
Income flexibility, retail level	0.331	0.507
Income elasticity, retail level 1/	.757	.737
Income flexibility, farm level	.667	.629
Income elasticity, farm level 1/	.757	.737

1/ Represents a lower bound; calculated as a reciprocal of the price flexibility.

Once again, we note that an unqualified reliance on the estimates derived here may be undesirable since the estimated coefficients are subject to simultaneous influences. With that in mind, the income elasticity for fresh apples is 1.07 and 0.733 for processing apples. In comparison, Tomek (1968) estimates an income elasticity of 3.42 for canned apples while income was not a significant explanatory variable for fresh apples. Waugh (1964) found a negative income flexibility at the farm level (-0.16) and a positive flexibility at the retail level (0.32) for fresh apples. Our study's income flexibility seems to be somewhat less extreme than either study.

Elasticities of Apple Supply

Relatively little empirical work has been done with respect to the supply side of the apple industry. There is an entirely reasonable answer for this gap since the comprehensive data, such as age distribution of orchards, that would be necessary to model the acreage response of a perennial crop are not available. However, one can still make some inferences using our model.

This section discusses the derivation of the elasticities of supply for fresh and processing apples at the grower and retail marketing levels. Our notation conforms with the two preceding sections deriving demand elasticities and all supply elasticities are evaluated at their means.

The elasticity of supply (ε^S) is generally defined as the percentage change in quantity supplied in response to a percentage change in price.

$$\varepsilon^S = \frac{\partial Q}{\partial P} \frac{P}{Q} \tag{5.1}$$

It can be shown that the linkage between the elasticity of supply at the grower level (ε^{SF}) and the retail market level is

$$\varepsilon^{SR} = \varepsilon^{SF} \left(\frac{1}{e}\right) \tag{5.2}$$

where the elasticity of supply at the retail level equals the product of the elasticity of supply at the grower level times the reciprocal of the elasticity of price transmission.

Using equations (5.1) and (5.2), one can derive estimates of the elasticities of supply for fresh and processing apples at the grower and retail market levels. Superscripts f and R refer to farm and retail levels, respectively, and subscripts F and P refer to fresh and processing apples, respectively.

Elasticity of Supply for Fresh Apples, Farm Level

$$\varepsilon_F^{SF} = \frac{\partial\,UTFR}{\partial\,PfR}\;\frac{PFR}{UTFR}$$

$$= (0.330 * 14.4073) * \frac{(5.648)}{3619.4}$$

$$= 0.007$$

Elasticity of Supply for Fresh Apples, Retail Level

$$\varepsilon_F^{SR} = \varepsilon^{SF}\left(\frac{1}{e_F}\right)$$

$$= 0.007 * \left(\frac{1}{0.496}\right)$$

$$= 0.004$$

Elasticity of Supply for Processing Apples, Farm Level

$$\varepsilon_P^{Sf} = \frac{\partial\,UTPR}{\partial\,PPR} * \frac{PPR}{UTPR}$$

$$= (186.592 + 0.670 * 80.0048) * \frac{2.338}{2366.9}$$

$$= 0.237$$

Elasticity of Supply for Processing Apples, Retail Level

$$\varepsilon_P^{SR} = \varepsilon_P^{Sf} * \left(\frac{1}{e_P}\right)$$

$$= 0.237 * \left(\frac{1}{0.595}\right)$$

$$= 0.398$$

The equation that describes allocation to the processing market suggests a farm-level elasticity of supply of 0.237 and a retail-level measure of 0.398. The elasticity of supply for fresh apples is 0.007 and 0.004 at the grower and retail-market levels, respectively. The estimates from our study are considerably smaller than those reported by Tomek (0.23 for fresh and 0.84 for canned apples) and Brandow (0.08 for fresh and 0.58 for canned) at the farm level. In addition, the fresh and processing market prices were not considered significant in the total utilization equation. Therefore, utilization is primarily explained by the level of production.

Impact Multiplier Market Analysis

An impact multiplier is defined as a change in an endogenous variable resulting from a specified change in a predetermined variable (see Intrilligater, 1978, p.499). The estimated reduced form system can be mathematically specified as:

$$Y_t = \hat{\pi} X_t$$

Y_t = vector of endogenous variables in time period t.

X_t = vector of predetermined variables in time period t.

$\hat{\pi}$ = matrix of restricted reduced form coefficients.

The matrix of impact multipliers is defined as:

$$\frac{\partial Y_t}{\partial X_t} = \hat{\pi}$$

Each of the predetermined variables is allowed to have an influence on all of the endogenous variables in the model because of simultaneity conditions. Our results show that production level and per capita expenditures exhibit the strongest influence on apple utilization and prices. The impact multipliers derived from the restricted reduced form coefficients are presented in table 3 for production and expenditures. As may be seen, a 100-million pound increase in total production results in a 95.9-million pound increase in total utilization. Approximately 4.1 million pounds of apples will not be utilized while 40 percent of the increase in production will enter the fresh market and 56 percent will enter the processing market. Apple prices will drop, in absolute level, more at retail than at the farm level. However, because of the less elastic demand at the farm level relative to the retail level, the percentage decline in prices will be greater for farm-level prices. In absolute levels, a 100-million pound increase in production results in a 0.091, 0.052, 0.27, and 0.05 cent per pound decline in retail fresh, farm fresh, retail processing, and farm processing price levels, respectively.

An increase of $100 in per capita real expenditures increases total utilization and all apple prices. A surprising effect of an expenditure increase is that a decrease in utilization of fresh market apples of nearly 8.23 million pounds is the result. There is a much stronger expenditure effect for processing market apples since total utilization in processing increases by almost 15.6 million pounds. Of this total, 7.358 million pounds will be from apples that would have not otherwise have been utilized and 8.23 million pounds are withdrawn from the fresh market and utilized in the processing market. The largest level in absolute price movement is observed for retail prices. Fresh apple prices increase over 3 cents per pound as do processing apple prices at retail. Farm-level prices increase 0.19 and 0.057 cents per pound for fresh and processing market apples, respectively.

Table 3--Selected impact mutliplier results

Variable	Units	Production increase of 100 mil. lbs.	Per capita expenditure increase of $100	100 mil. lb. decrease in fresh market utilization - 100 mil. lb. increase in processing market utilization
UTIL	(mil. lbs.)	95.91	7.358	0
UTFR	(mil. lbs.)	40.39	-8.225	-100.00
UTPR	(mil. lbs.)	55.52	15.583	100.00
RPFAP	(¢/lb.)	-.091	.3350	.22
PFR	(¢/lb.)	-.052	.1919	.126
WPAPSB	(¢/lb.)	-.27	.3338	-.49
PPR	(¢/lb.)	-.047	.0574	-.08

Pesticide Analysis

The multipliers derived and presented in table 3 can be used to assess the impact on the apple sector of a pesticide withdrawal from the market. Assume that the pesticide in question, pesticide X, is used extensively in the apple sector. Withdrawal of the chemical may result in 1) a decrease in total production of apples, 2) a decrease in the quality of the crop, 3) a combination of (1) and (2), or 4) no change in quantity or quality. For simplicity, two cases will be presented.

Case 1

Case 1 assumes that a reduction in the apple crop of 100 million pounds results from the loss of pesticide X. The loss in fresh market apples will be assumed to enter the processing sector. Further, the analysis will be based on the 1982 crop year. Total utilization for 1982 was 8,810 million pounds: 4,942 million pounds fresh utilization and 3,868 million pounds processing market utilization. The deflated farm-level fresh apple, retail-level fresh apple, farm-level processing apple and retail-level processing apple prices were 4.12, 21.26, 1.43, and 12.70 cents per pound, respectively.

The multipliers for production in table 3 can be used to assess the outcome. Total utilization declines by 1 percent or 95.9 million pounds. Fresh market utilization declines by 40.8 million pounds (0.9 percent) and processing utilization falls by 56 million pounds (2 percent). Fresh market apple prices rise to 4.17 and 21.35 cents per pound at the farm- and retail-market levels, respectively. Processing apple prices at the farm and retail levels increase by 0.05 and 0.27 cents per pound, respectively.

Case 2

The second case to be examined assumes that the absolute level of production remains unchanged, but the quality of the fresh market apple crop declines. As a consequence of the withdrawal of pesticide X fresh market utilization declines by 100 million pounds and utilization in the processing sector increases by 100 million pounds. The results of these assumption are also shown in table 3.

Assuming the 1982 year again, fresh market apple prices should increase 0.22 and 0.13 cents per pound at retail and the farm level. Processing market apple prices are expected to decline as a result of this reallocation of supplies by 0.49 and 0.08 cents per pound at the retail and farm level, respectively. In terms of 1982 utilization and price levels, fresh utilization declines 2 percent, processing utilization increases 2.6 percent, fresh apple prices increase by 0.9 and 1.9 percent at the retail and farm market levels, respectively, and processing apple prices decrease by 3.9 and 5.6 percent at the retail and farm markets, respectively.

Summary and Conclusions

This study has conceptualized and estimated an aggregate simultaneous demand model of the U.S. apple sector. Apples were disaggregated into fresh market and processing market quantity and the farm and retail levels were identified. Empirical results indicated that the demand for both fresh and the processing apple market are more elastic at the retail level than at the farm level as is the case for most commodities.

The empirical results were then used to derive impact multipliers for selected variables. Total apple production and real per capita expenditures have the most marked effect on prices and quantities utilized. A pesticide withdrawal analysis was presented using the derived multipliers. If the withdrawal affects total production, then in the shortrun impacts are distributed between the fresh and processing markets. However, if the withdrawal affects only the quality of the fresh market crop, then fresh market prices increase and processing prices decline.

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Appendix I--Variable Series Sources and Definitions

EXP = per capita expenditures income, 1,000 dollars, calendar year basis
Source: Working Data for Demand Analysis, deflated by CPI.

MARFR = fresh apple marketing margin, cents per pound
Source: calculated RPFAP - PFR.

MARPR = processing apple marketing margin, cents per pound
Source: calculated, WPAPSB - PPR.

OTHPRC - total consumption of processed fruit excluding apple products, million pounds, calendar year basis
Source: calculated, total processed fruit consumption less processed apple consumption: Agricultural Statistics, 1972, 1979 issues.

OTHPRD = quantity of apples not utilized in either the fresh or processing market, million pounds, marketing year September-August
Source: calculated as a residual, PROD - UTFR - UTPR.

PFR = average price received by growers for fresh market apples, cents per pound
Source: Non-Citrus Fruit and Nuts and Agricultural Prices, deflated by PPI.

PORIR = U.S. retail pork price, index
Source: Bureau of Labor Statistics.

PPR = average price received by growers for processing grade apples, cents per pound
Source: Non-Citrus Fruits and Nuts and Agricultural Prices, deflated by PPI.

PROD = total quantities of apples produced in the United States, million pounds, marketing year September-August
Source: Agricultural Statistics, 1972, 1976, 1979 issues.

RPFAP = retail price of fresh market apples, cents per pound, calendar year basis
Source: Retail Prices of Food by Cities, deflated by CPI.

STCAP = beginning stocks of canned apples, 1,000 lbs.
Source: The Almanac.

TRANS = index of all urban consumers transportation CPI (1967=100), calendar year basis

USORAN = total quantities of oranges produced in the United States, 1,000 tons
Source: Agricultural Statistics, 1972, 1976, 1979 issues.
Source: Bureau of Labor Statistics.

UTFR = quantity of apples utilized in the fresh market, million pounds, marketing year September-August
Source: Agricultural Statistics, 1972, 1976, 1979 issues.

UTIL = quantity of apples utilized in both the fresh and processing markets, million pounds, marketing year September-August
Source: Agricultural Statistics, 1972, 1976, 1979 issues.

UTPR = quantity of apples utilized in the processing market, million pounds, marketing year September-August
Source: Agricultural Statistics, 1972, 1976, 1979 issues.

WPAPSB = wholesale price of apple sauce, cents per pound, calendar year basis
Source: Fruit Situation, deflated, by CPI.

Appendix II--Model Evaluation

The estimated structural model was evaluated over the 1952-81 sample period. The model was examined for 1) coefficient signs being consistent with theory and/or *a priori* expectations, 2) mean absolute error (MAE), 3) mean absolute percent error (MAPE), and 4) mean squared error (MSE). Coefficient signs were as expected.

The MAE, MAPE, and MSE results are summarized in appendix table 1. The MAE for total utilization, fresh utilization, and processing utilization appears large, but in terms of MAPE each is relatively small, with less than a 10-percent error. The not-utilized category shows the largest degree of error as measured by the MAE and MAPE. This is not surprising since the category is small in magnitude and errors appear large in percentage terms. The MAPE is 538.8 percent.

The MSE error for all quantities of apples utilized and not utilized is fairly large. For each of these variables, the MSE exceeds the mean of the particular variable. This suggests that the structure for these variables should be re-examined.

The results for all prices and margins are promising. The MAE for each is less than or equal to 2.26 cents per pound. The largest MAPE is for the farm-level price of processing apples and the next largest is for wholesale processing prices. This may be explained partly by the fact that wholesale apple sauce price only imperfectly proxys a retail processing price for apples. In addition, the data was spliced with aggregate fruit price CPI. Even so, the MAPE is less than 16.12 percent for all price variables.

The MSE results for the price variables are also favorable. Each of the measures is less than 28 cents per pound. The smallest MSEs are for farm-level prices.

In general, the estimated model appears to be acceptable. The evaluation criteria do not raise serious questions as to the validity of the estimated model. The MSE criteria may lead one to question the utilization structure. However, the MAE and MAPE analyses do not support a reexamination of the utilization components and the model evaluation is overall favorable.

Appendix table 1--Evaluation Statistics

Item	Mean 1/	Mean absolute error 2/	Mean absolute percent error 3/	Mean squared error 4/
UTIL (mil. lbs.)	5986	73.6	1.26	379978
UTFR (Mil. lbs.)	3619	173.0	4.77	1220529
UTPR (mil. lbs.	2367	192.4	9.22	1602796
OTHPROD (mil. lbs.)	95	74.5	538.79	381579
RPFAP (¢/lb.)	19.87	.81	4.06	28.54
PFR (¢/lb.)	4.65	.47	8.66	8.66
MARFR (¢/lb.)	6.24	.58	4.03	11.52
WPAPSB (¢/lb.)	16.86	2.26	14.13	20.034
PPR (¢/lb.)	2.34	.36	16.12	6.19
MARPR (¢/lb.)	19.505	1.08	7.45	50.93

1/ Simple average, 1952-1981.

2/ Mean absolute error (MAE) is defined as:

$$MAE = \frac{\sum_{t=1951}^{1981} |P_t - A_t|}{31}$$

where P_t is the predicted value and A_t is the actual value.

3/ Mean absolute percent error (MAPE) is defined as:

$$MAPE = \frac{\sum_{t=1952}^{1981} \frac{|P_t - A_t|}{A_t} * 100}{31}$$

where P_t and A_t are as defined in 2/.

4/ Mean squared error (MSE) is defined as:

$$MSE = \sum_{t=1951}^{1981} (P_t - A_t)^2$$

where P_t and A_t are as defined in 2/.